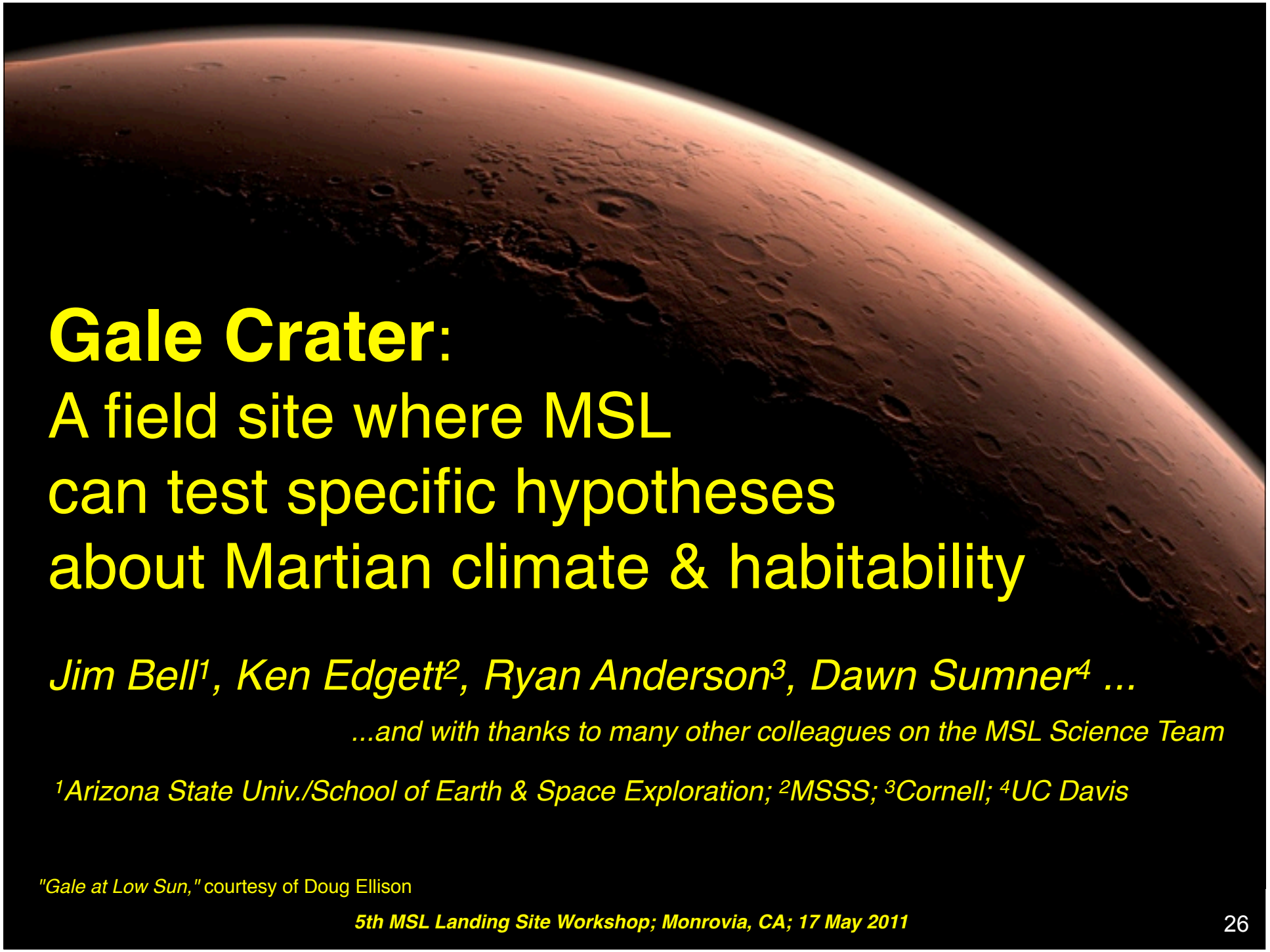


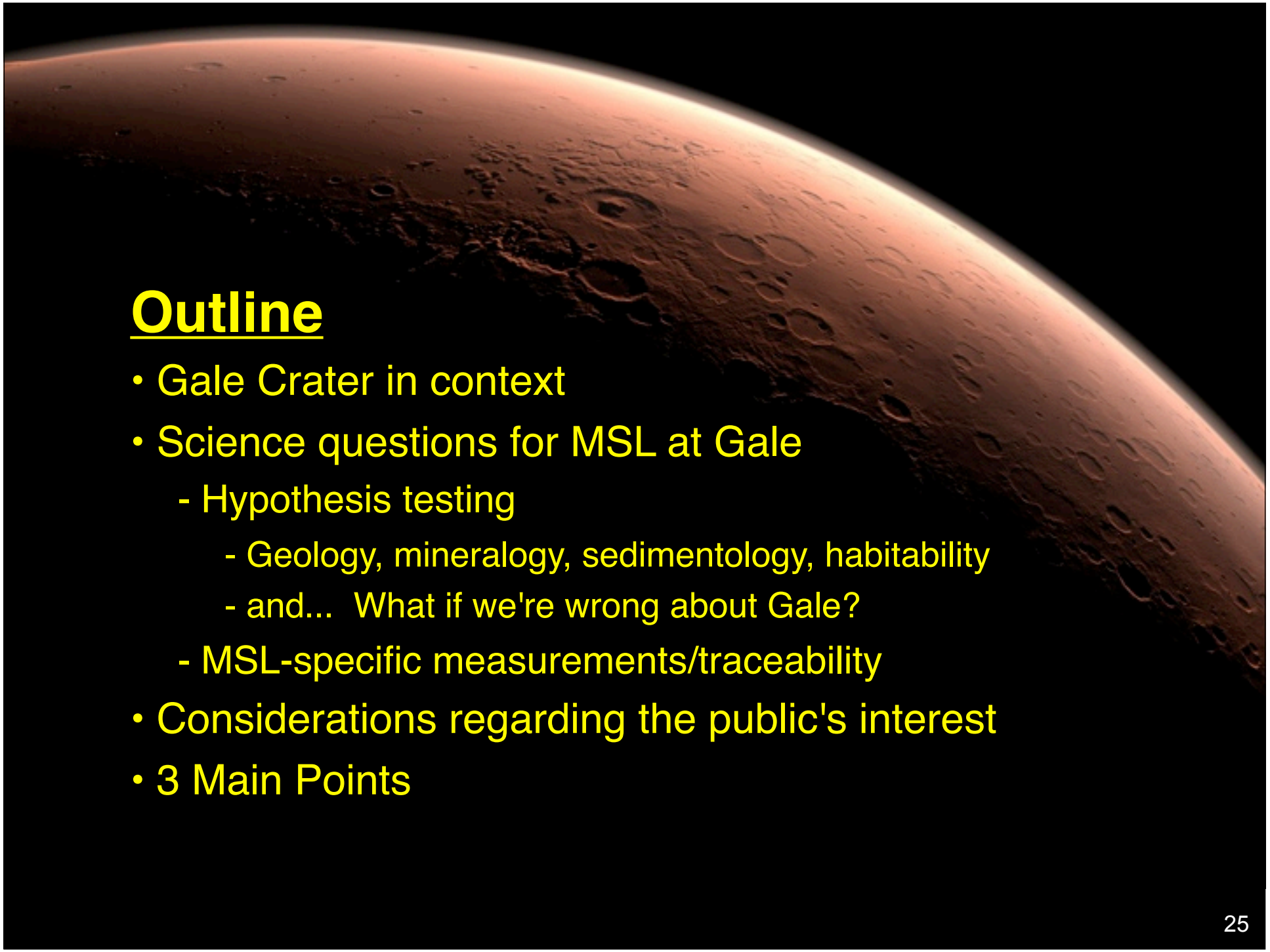
Gale Crater: A field site where MSL can test specific hypotheses about Martian climate & habitability

Jim Bell[1], Ken Edgett[2], Ryan Anderson[3], Dawn Sumner[4] ...

...and with thanks to many other colleagues on the MSL Science Team

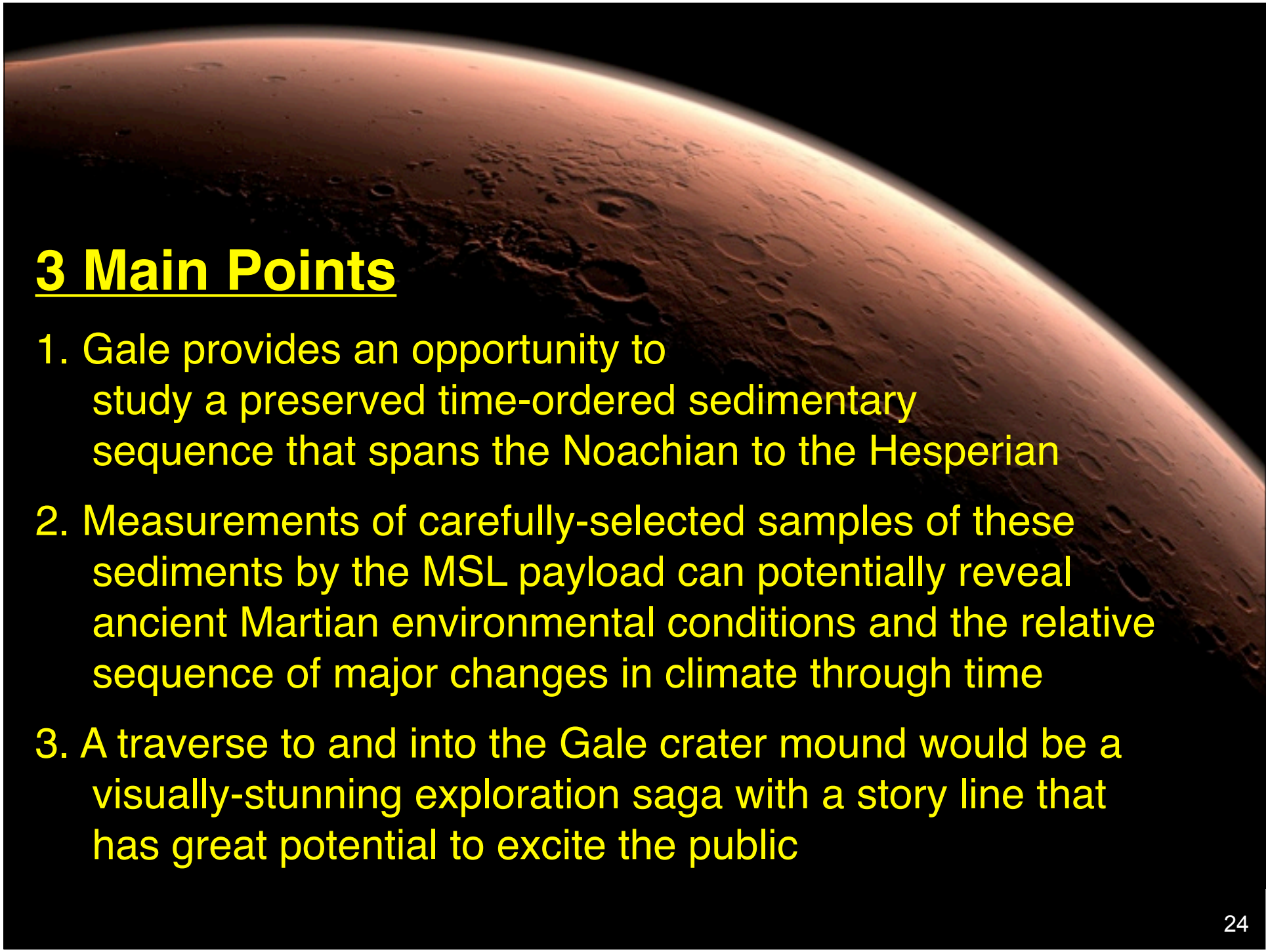
[1]Arizona State Univ./School of Earth & Space Exploration; [2]MSSS; [3]Cornell; [4]UC Davis

"Gale at Low Sun," courtesy of Doug Ellison



Outline

- Gale Crater in context
- Science questions for MSL at Gale
  - Hypothesis testing
    - Geology, mineralogy, sedimentology, habitability
    - and... What if we're wrong about Gale?
  - MSL-specific measurements/traceability
- Considerations regarding the public's interest
- 3 Main Points

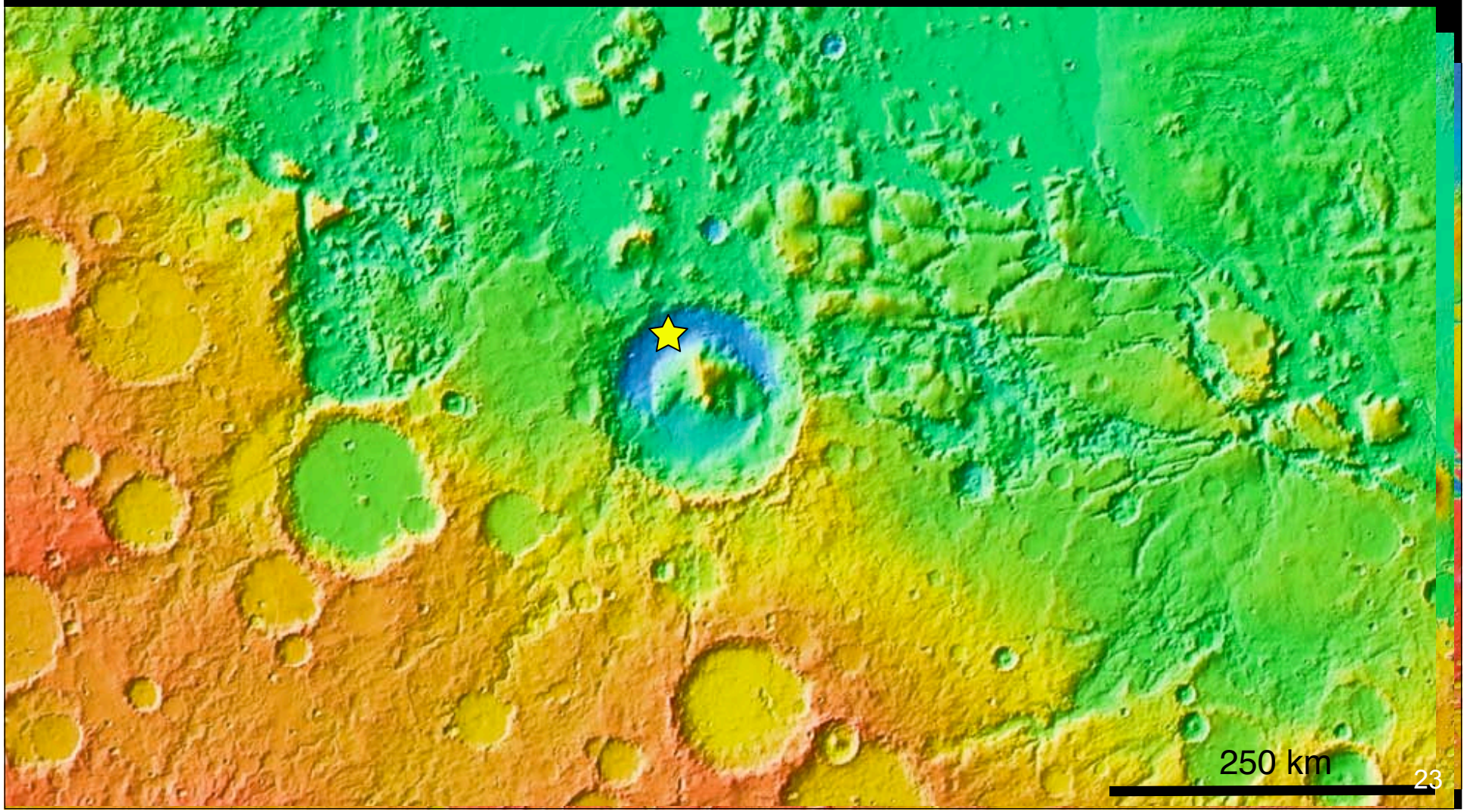


3 Main Points

1. Gale provides an opportunity to study a preserved time-ordered sedimentary sequence that spans the Noachian to the Hesperian
2. Measurements of carefully-selected samples of these sediments by the MSL payload can potentially reveal ancient Martian environmental conditions and the relative sequence of major changes in climate through time
3. A traverse to and into the Gale crater mound would be a visually-stunning exploration saga with a story line that has great potential to excite the public

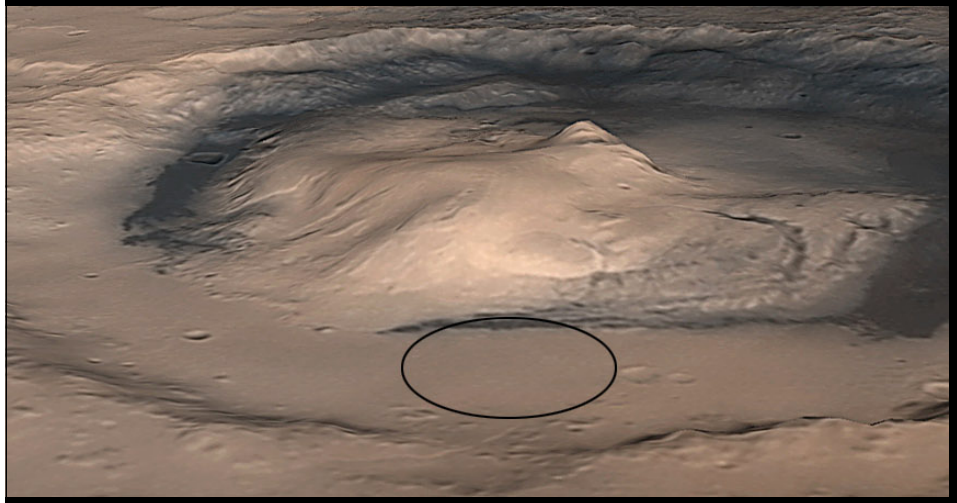
Gale Crater in Context

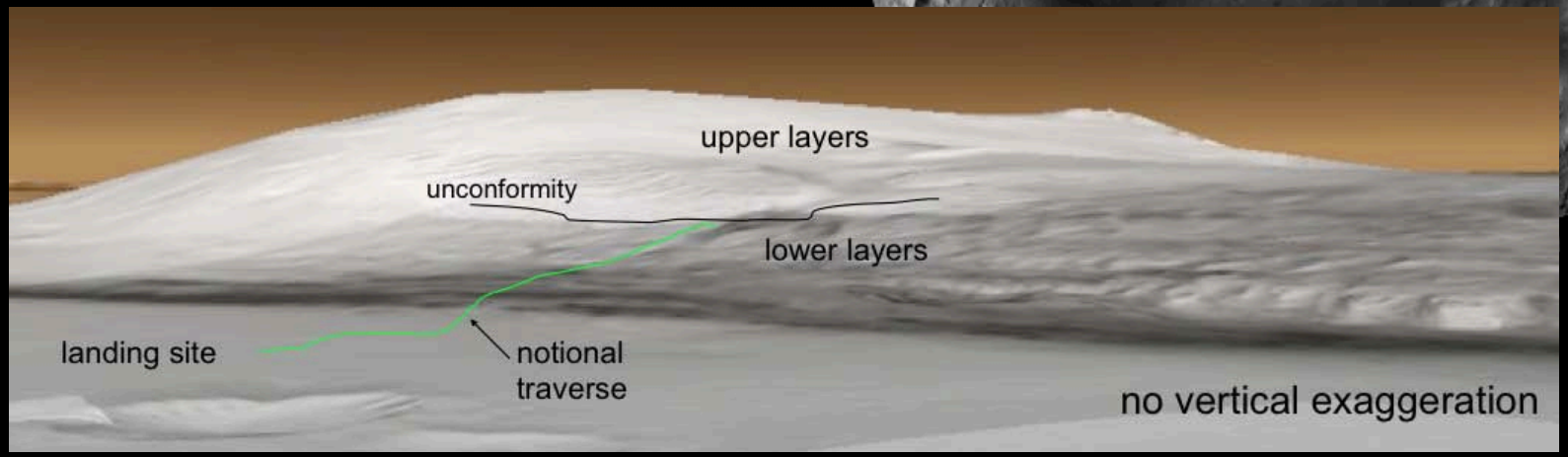
- You have just heard this story from Ken Edgett
- But it is worth some (brief, visual) reiteration...



Gale Crater in Context

- How does Gale "fit" with our knowledge of Mars?
- What can we learn about Mars from Gale?





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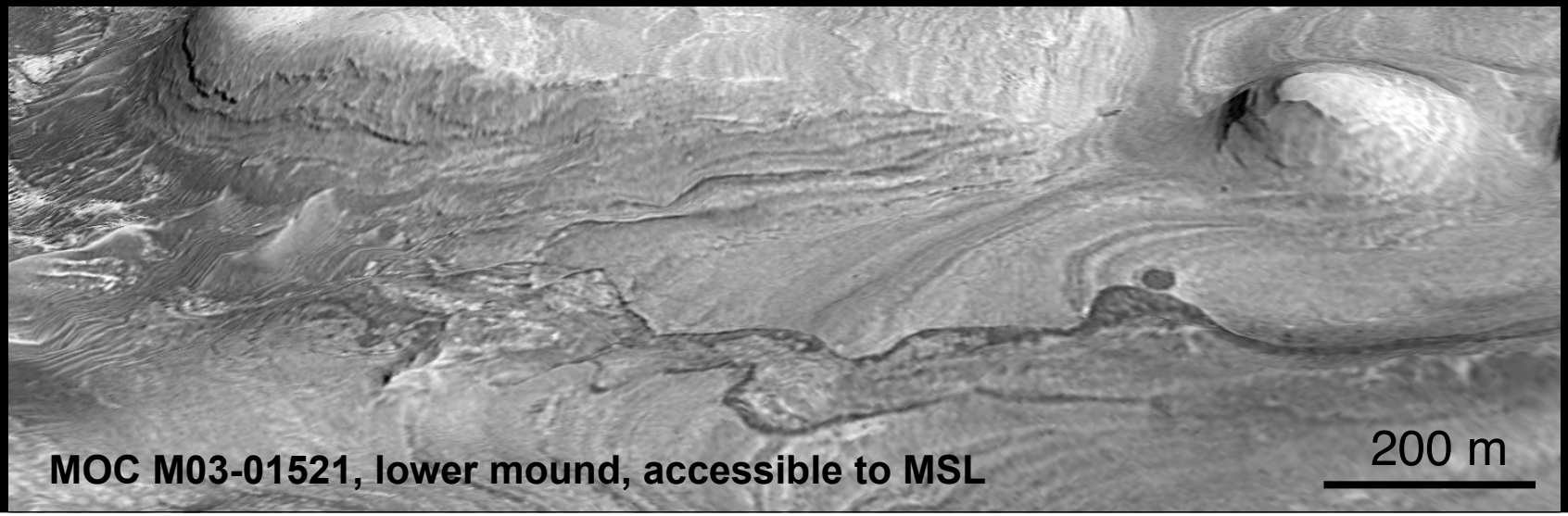
Examples:

- Role of liquid water (and lacustrine processes?) in sediment deposition, erosion, transport, cementation, and mineral weathering



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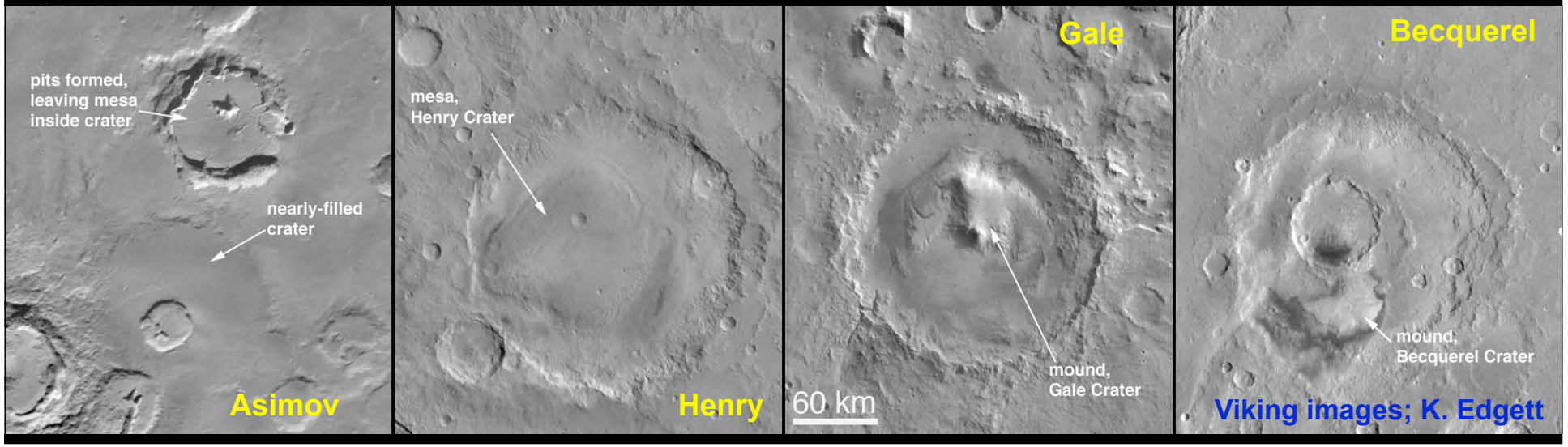

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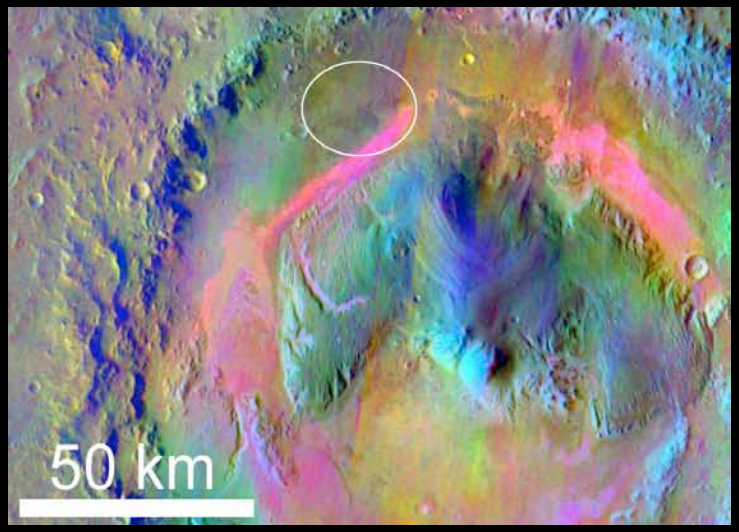

THEMIS 875 DCS
Stockstill *et al.*, 2007
Hamilton *et al.*, 2009

Gale Crater in Context

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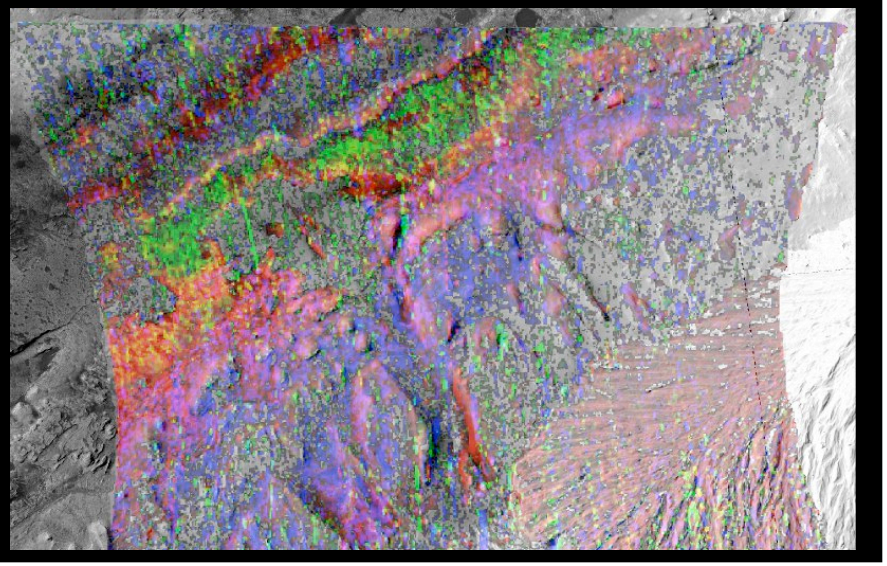
olivine (dunes); $(Mg,Fe)_2SiO_4$
pyroxene (LCP & HCP) in/near mound
(Fe, Mg) smectite clays; *e.g.,*
nontronite $Fe_2(Si,Al)_4O_{10}(OH)_2 \cdot n(H_2O)$
sulfates (monohydrated)
e.g., kieserite $MgSO_4 \cdot H_2O$
sulfates (polyhydrated)
sulfates & clays
& crystalline red hematite



CRISM, OMEGA
Milliken *et al.*, 2010; Anderson & Bell, 2010

Hypothesis Testing at Gale

"In choosing a hypothesis there is no virtue in being timid.
I clearly would have been burned at the stake in another age."
- Tommy Gold

Hypothesis Testing at Gale

1a. Liquid water flowed into, and within, Gale crater

1b. Some of the sediments on the floor and central mound of Gale were deposited in a subaqueous environment

1c. For some period of its history, Gale hosted a lake

2a. Sedimentary deposits within Gale crater preserve a record of environmental conditions and habitability on early Mars

2b. The coherence of the physical stratigraphy and mineralogic diversity in Gale provides special opportunities to optimize the search for organics and other habitability markers

3. The origin of hydrated sulfate and phyllosilicate minerals at Gale crater can be determined by *in situ* MSL data

HiRISE DEM
R. Kirk, USGS

Hypothesis Testing at Gale

1a. Liquid water flowed into, and within, Gale crater

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- 1a can be tested on the fan within the ellipse, along the traverse to the mound, and within the lower mound
- The best places to test 1b are the lowermost layers of the mound (the part accessible to MSL). We don't have to climb very high up! (though that would be cool...)
- Testing of fluvial *vs.* subaqueous *vs.* subaerial deposition requires close-up geologic/textural/compositional study

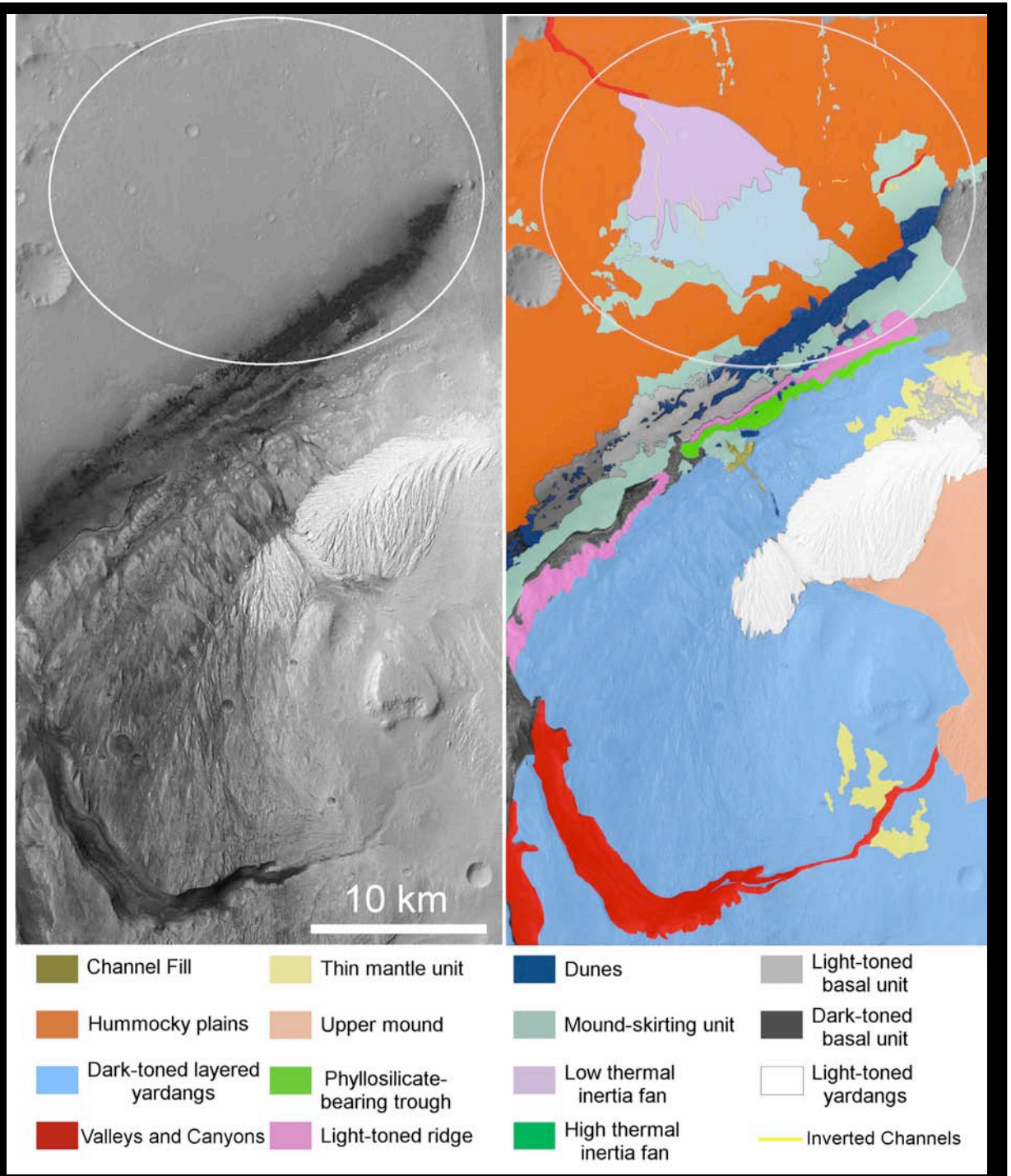
HiRISE DEM
R. Kirk, USGS

Gale Unit Mapping

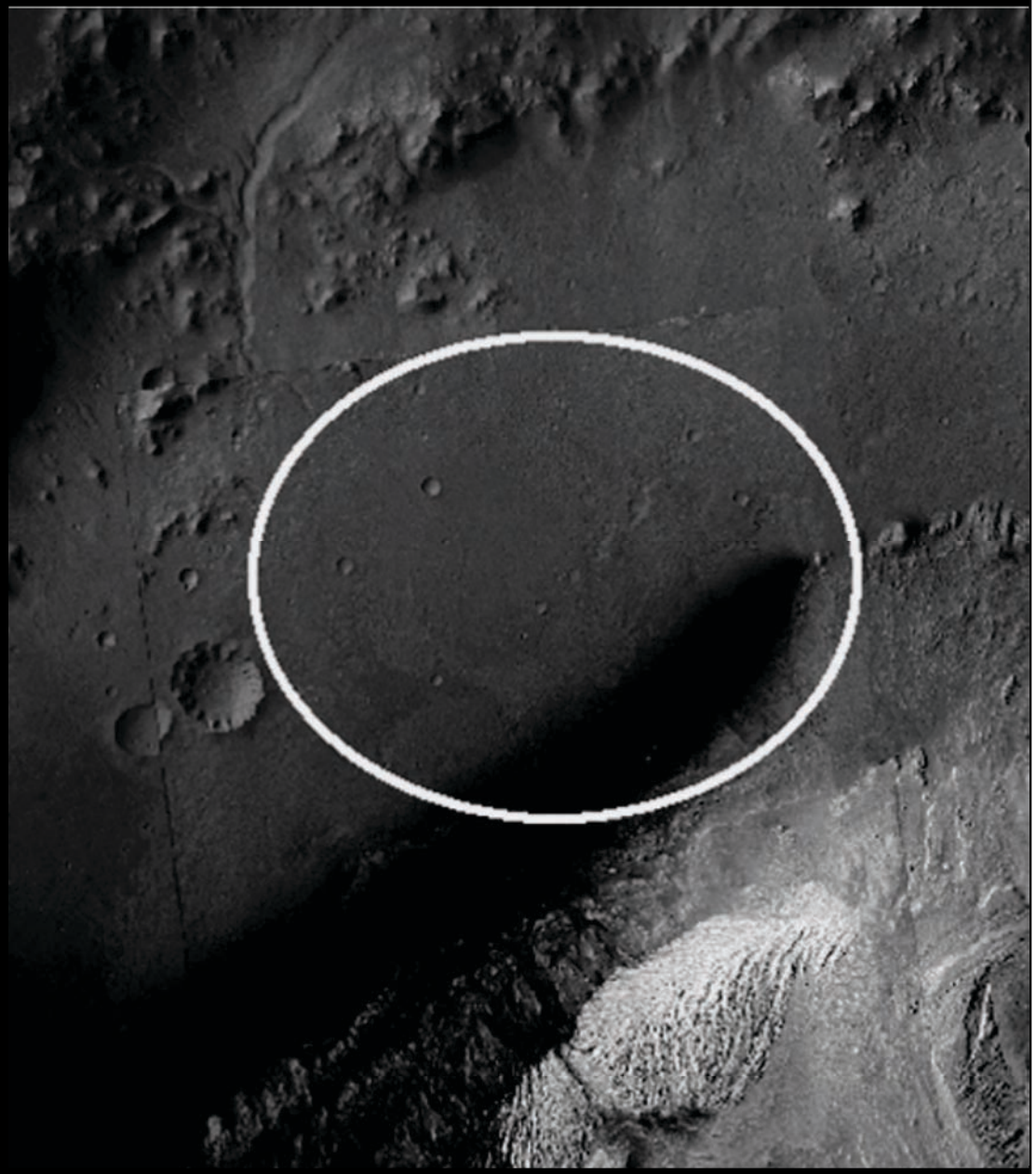
- thermal inertia
- geomorphology
- mineralogy

Lots more detail in Ryan Anderson's paper in the online *Mars* journal: http://dx.doi.org/doi:10.1555/mars.2010.0004

(Anderson & Bell, 2010)

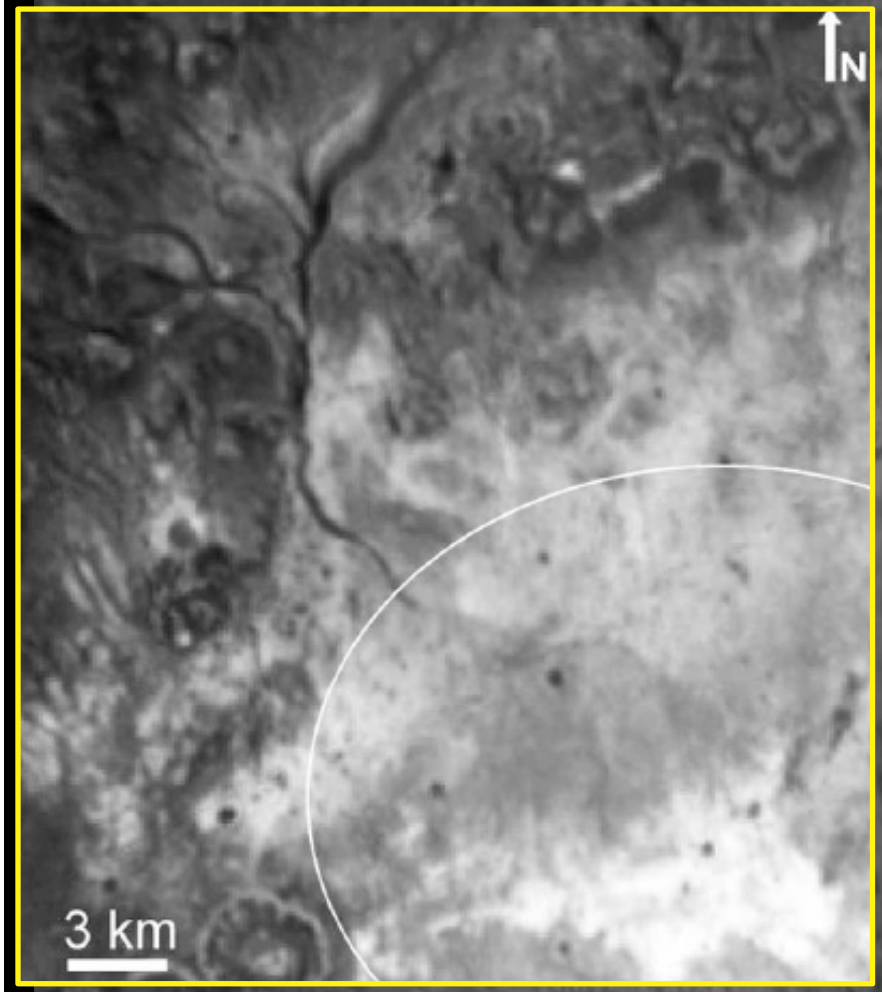


Landing ellipse distributary fan



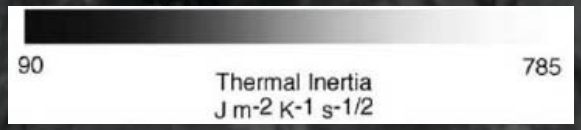
CTX Mosaic

ODY/THEMIS
Thermal Inertia

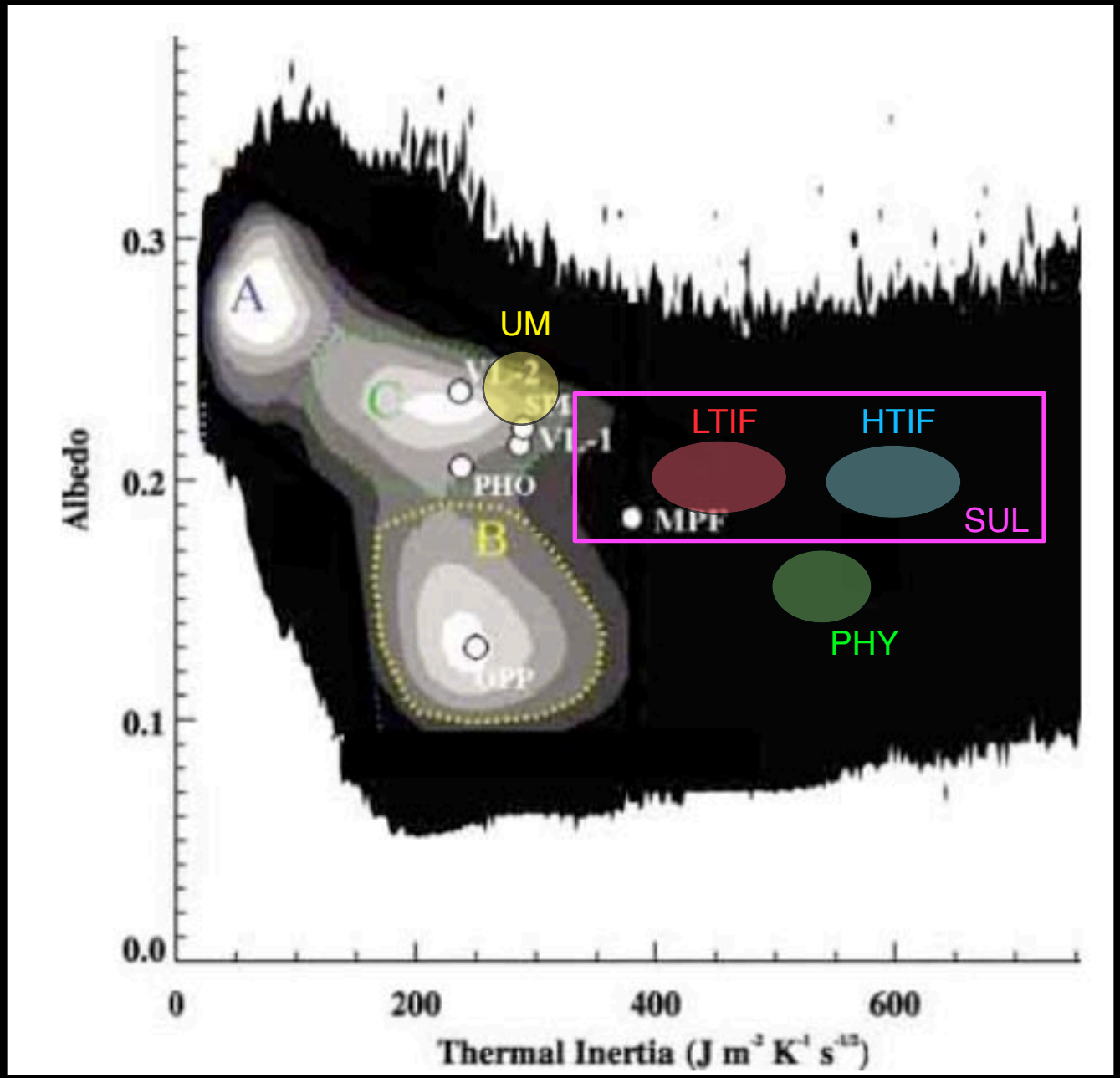


(Fergason *et al.*, 2006)
(also Hobbs *et al.*, 2010)

- High Albedo
- High TI
- High potheses?
  - Cementation of fan sediments
    - by sulfates (masked by dust)?
    - by chlorides (spectrally neutral)?
    - by ferricrete/ferric oxides?
  - Other lithified sedimentary rock?
  - Highly eroded lava flow?



NASA/JPL/ASU



Golombek *et al.*, 2009
Anderson & Bell, 2010

Example Gale Units:

UM: Upper Mound

LTIF: Low Thermal Inertia Fan

HTIF: High Thermal Inertia Fan

PHY: Phyllosilicate-bearing unit

SUL: Sulfates

TES Thermal Inertia *vs.* albedo for the six landing sites and the 3 modes that make up 80% of the surface

Hypothesis Testing at Gale

1a. Liquid water flowed into, and within, Gale crater

1b. Some of the sediments on the floor and central mound of Gale were deposited in a subaqueous environment

1c. For some period of its history, Gale hosted a lake

- Of course, there is some uncertainty in the community about the validity of this hypothesis!
- But if any aspect of this hypothesis is *wrong* (fluvial, subaqueous, lacustrine), then the result is extremely important for our understanding of Mars overall!

There are two possible outcomes: If the result confirms the hypothesis, then you've made a measurement. If the result is contrary to the hypothesis, then you've made a discovery.

- Enrico Fermi

HiRISE DEM
R. Kirk, USGS

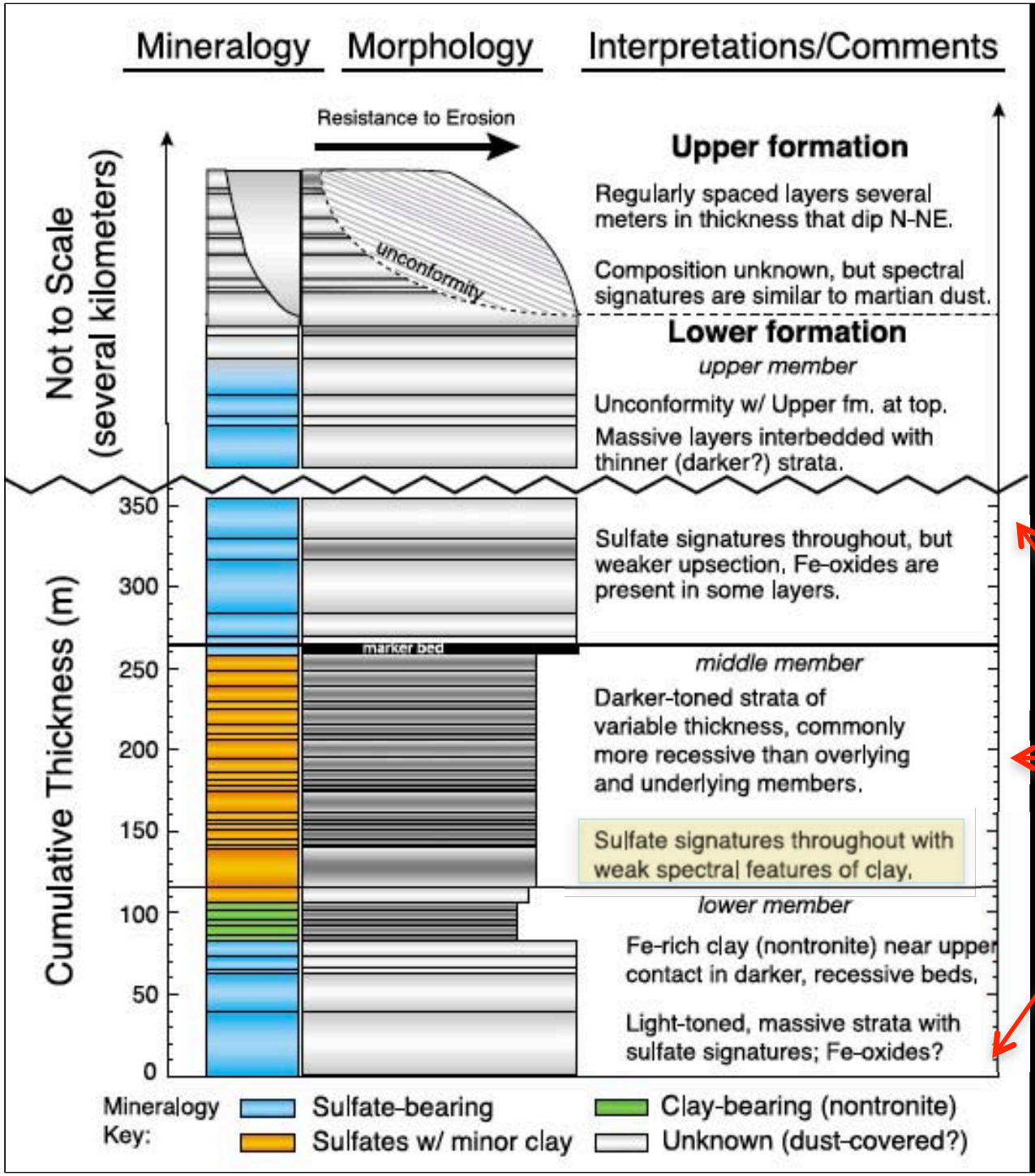
Hypothesis Testing at Gale

2a. Sedimentary deposits within Gale crater preserve a record of environmental conditions and habitability on early Mars

2b. The coherence of the physical stratigraphy and mineralogic diversity in Gale provides special opportunities to optimize the search for organics and other habitability markers

- Gale gives access to enough stratigraphy that MSL could assess the habitability of multiple environments.
- The thicker the stratigraphic section, the longer and more varied the record of environments and environmental change is likely to be.

HiRISE DEM
R. Kirk, USGS



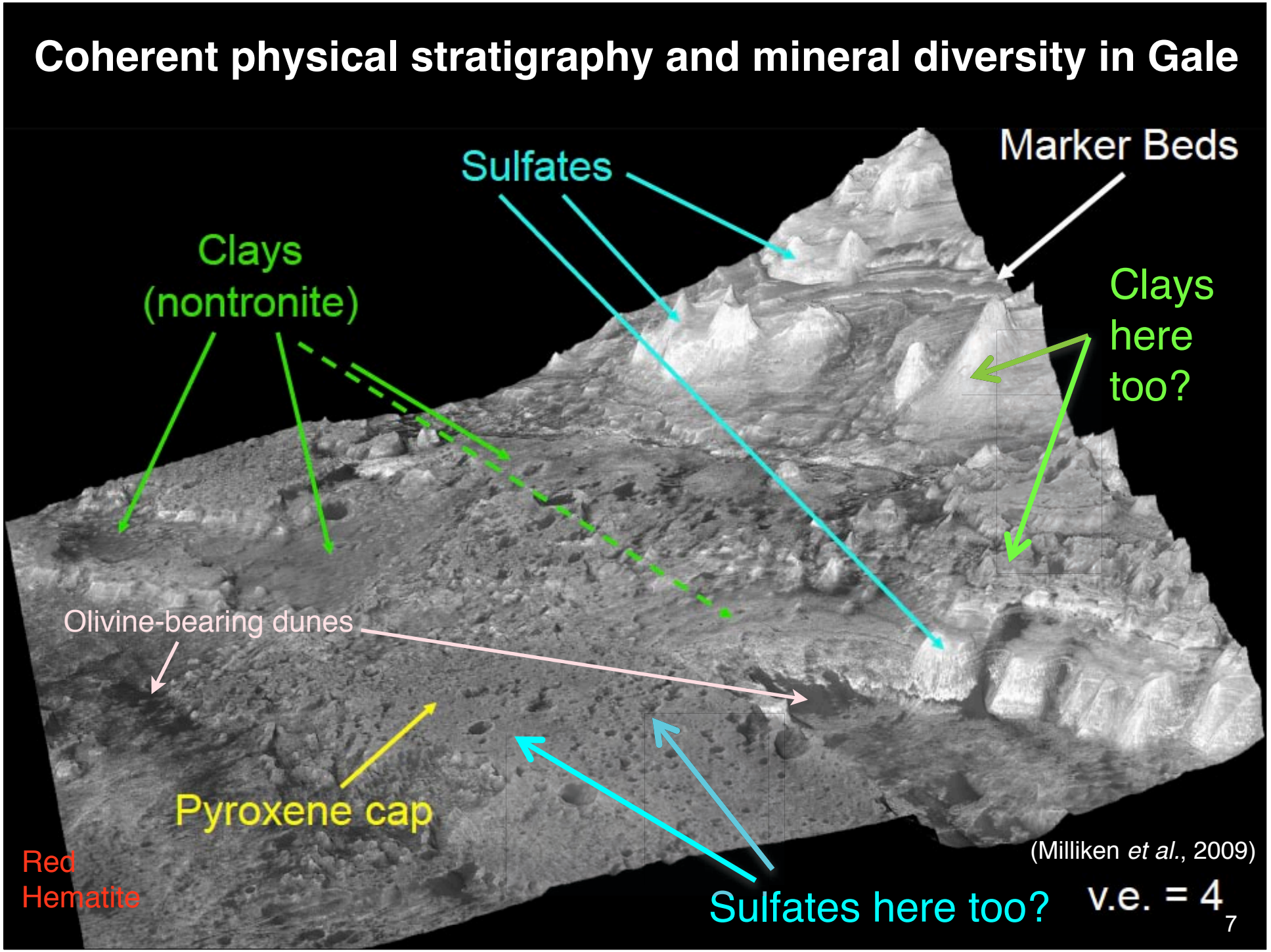
An Inferred Stratigraphic Column for a Section of the Gale Mound

(Milliken *et al.*, 2010)

This part of the section would be the primary focus of study by MSL

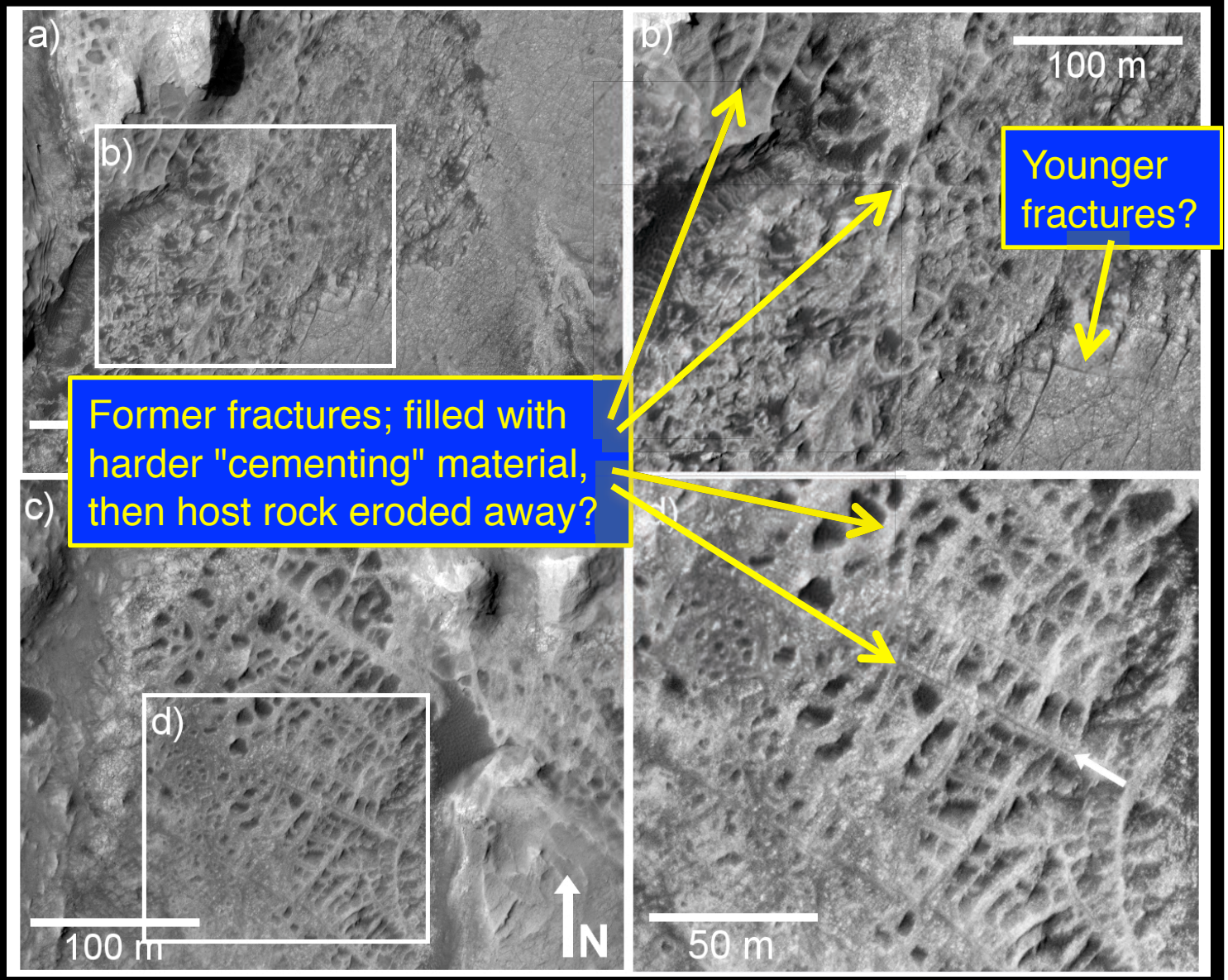
(lowest 100-200 m could be the "performance floor" for the mission)

Coherent physical stratigraphy and mineral diversity in Gale



Erosion-resistant ridges in the sulfate-bearing unit

Fractures are relatively common in Gale, both on the mound and in the ellipse...



(Anderson & Bell, 2010)

from HiRISE PSP_001752_1750; NASA/JPL/Univ. Arizona

Hypothesis Testing at Gale

3. The origin of hydrated sulfate and phyllosilicate minerals at Gale crater can be determined by *in situ* MSL data

- **PROCESS**: Dissolution and remobilization of salts? Diagenesis? Playa? Sabkha? Deep water/evaporite? Groundwater? Acid fog?

- Determining whether the phyllosilicates are authigenic or detrital should be possible with detailed textural, compositional, and contextual data from MSL

(same as for Mawrth, Eberswalde, and Holden!)

HiRISE DEM
R. Kirk, USGS

Science Traceability: Goals → Measurements → Instruments

(Partial) Science Traceability Matrix for the MSL Payload at Gale Crater		
Science Goal	*Measurement Objective*	*Instruments/Observations*
Determine the origin, style, and history of aqueous alteration at the field site	Identify specific alteration minerals	CheMin, SAM, APXS, ChemCam
	Characterize grain sizes, shapes, textures, and their relation to other constituents	MAHLI, ChemCam, Mastcam
	Assess style and degree of alteration and biologic habitability potential	CheMin, SAM, APXS, Chemcam
Determine the origin(s) of the observed layers	Detailed examination of constituent particles: grain size, degree of sorting, shape, texture, degree of alteration	MAHLI, ChemCam, Mastcam
	Identify and characterize bedding relationships and sedimentary structures	Mastcam, ChemCam (+ HiRISE)
	Identify primary mineralogies as well as secondary alteration products and cementing agent	CheMin, SAM, APXS, ChemCam

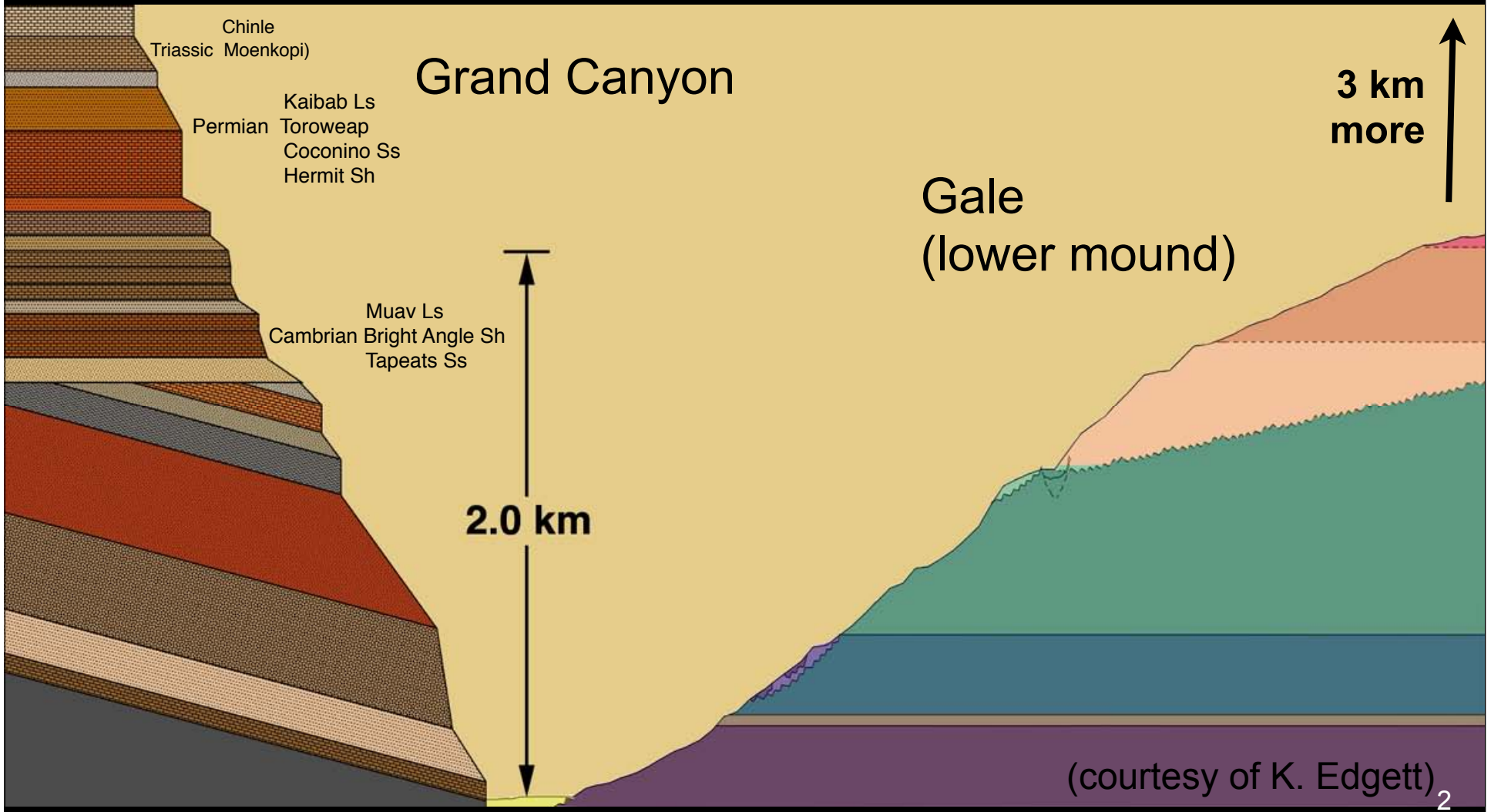
Updated from Thomson *et al.* (2007)

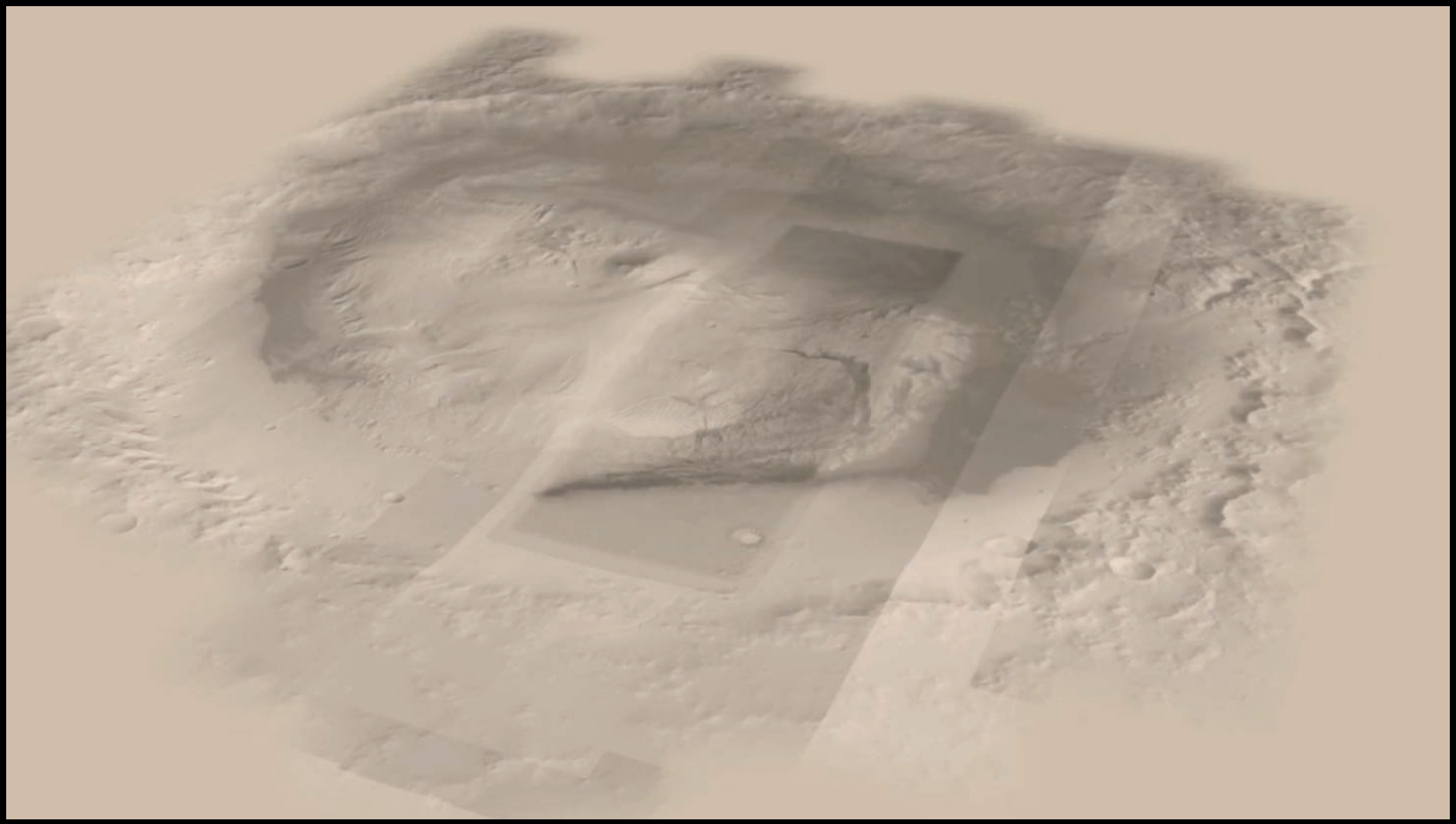
Public Interest in MSL

Personal observations:

- We must pay close attention to how we can be the best stewards of $2.5B in U.S. taxpayer investment in MSL (plus international taxpayer investment too!)
- We need to be able to share a compelling story about our mission at our field site, and what the results could mean for life on Mars as well as life on Earth
- Our story should be told in visually stunning as well as scientifically exciting ways, and framed in the context of the rich history of Earth & planetary exploration

- The Gale mound is in places up to 5 km high.
- The stratigraphy accessible to MSL only covers the lower few kilometers
- This figure is a comparison with the thickness of the Grand Canyon strat column
- There is, of course, a complex story recorded in the rocks at the Grand Canyon...
  - and there was a compelling story about its exploration told by John Wesley Powell and crew...





What falls there are, we know not; what rocks beset the channel, we know not; what walls ride over the river, we know not. Ah, well! we may conjecture many things... With some eagerness, and some anxiety, and some misgiving, we enter the canyon below, and are carried along by the swift water...

--John Wesley Powell, *The Exploration of the Colorado River*, 1869

Gale animation using a HiRISE DTM draped over a CTX DTM and a CTX mosaic; No vertical exaggeration

Courtesy of Doug Ellison

3 Main Points

1. Gale provides an opportunity to study a preserved time-ordered sedimentary sequence that spans the Noachian to the Hesperian*
2. Measurements of carefully-selected samples of these sediments by the MSL payload can potentially reveal ancient Martian environmental conditions and the relative sequence of major changes in climate through time
3. A traverse to and into the Gale crater mound would be a visually-stunning exploration saga with a story line that has great potential to excite the public

*and to today